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(54) Title: SECURITY PRINTING			
(57) Abstract			
<p>A method of providing covert security features for documents such as vouchers, packaged goods and banknotes in which the document is provided with a dopant. The dopant consisting of a material which can be identified by examination of its response to visible wavelength photon radiation and which can be applied directly on or into the document or can be fused into glass matrices before application.</p>			

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1 **SECURITY PRINTING**

2

3 The invention relates to materials and techniques
4 relating to security printing.

5

6 The present invention in its broadest sense is
7 concerned with the provision of security in relation to
8 documents, vouchers, packaged goods and tokens of
9 value. Examples of these are banknotes, cheques and
10 drafts, bond and stock certificates, and credit and
11 bank cards. All of these are referred to hereinafter
12 for simplicity as "documents".

13

14 Documents of this nature have the requirement to be as
15 secure as possible against forgery and falsification
16 and for this purpose it is desirable that they exhibit
17 both covert and overt security features. The
18 expression "covert security feature" is used to denote
19 some security feature which is not visually apparent to
20 the normal user, whereas "overt security feature" is
21 used to denote a feature which can be readily seen and
22 recognised by members of the public without the use of

1 specialised equipment or confidential information.
2 Traditional forms of overt security features include
3 water marks, metal security threads, and the use of
4 specialised forms of paper and printing.

5

6 Known methods of covert security include NIR and IR
7 absorber inks, magnetic threads, complex optical and
8 electrically conductive indicia, anti-Stokes, visible-
9 wavelength-emitting phosphors etc.

10

11 With rapid advances in reprographic technology such as
12 relatively cheap and high quality colour photocopiers
13 and easily available digital image manipulation, the
14 traditional forms of security have become increasingly
15 easy to circumvent. This is because the absorption and
16 emission in the visible, NIR and IR ranges of all the
17 currently used and proposed security dopants are
18 readily available in the public domain since the
19 current materials were developed for the laser and lamp
20 industries. This is particularly true for all the rare
21 earth containing absorbers and emitters, where many
22 thousands of public domain references of absorption and
23 emission spectra are listed from the 1950's onwards.
24 There is accordingly a requirement for improved forms
25 of both covert and overt security features, preferably
26 ones which can be used with existing printing
27 technology at modest cost.

28

29 According to one aspect of the present invention, there
30 is provided a method of providing a document with a
31 covert security feature, in which the document is

1 printed using an ink containing a dopant, the dopant
2 being of a material which can be identified by
3 examination of its response to visible wavelength
4 photon radiation.

5

6 This and other aspects and features of the present
7 invention are defined in the appended claims.

8

9 The present invention will now be described by way of
10 example with reference to the accompanying drawings of
11 which:

12

13 Fig. 1 shows a blue ink reflectance spectrum from a
14 paper print;

15

16 Fig.2 shows green ink reflectance spectrum from a paper
17 print;

18

19 Fig.3 shows red ink reflectance spectrum from a paper
20 print;

21

22 Fig.4 shows a reflectance spectrum from the
23 Praesodymium Oxide dopant in accordance with the
24 present invention;

25

26 Fig.5 shows a reflectance spectrum from the Neodymium
27 Oxide dopant in accordance with the present invention;

28

29 Fig.6 shows a reflectance spectrum from the Holmium
30 Oxide dopant in accordance with the present invention;

1
2 Fig.7 shows a reflectance spectrum from the Thulium
3 Oxide dopant in accordance with the present invention;
4
5 Fig.8 shows a reflectance spectrum of raw Europium
6 Oxide powder as used in the present invention;
7
8 Fig.9 shows a reflectance spectrum of the same
9 Europium Oxide contained in glass;
10
11 Fig.10 shows a reflectance spectrum of raw Erbium Oxide
12 powder as used in the present invention;
13
14 Fig.11 shows a reflectance spectrum of the same Erbium
15 Oxide contained in glass;
16
17 The present invention provides a range of inorganic
18 dopants designed with absorption spectra sufficiently
19 different in form and structure from the absorption
20 spectra of printing inks so that the dopants can be
21 easily identified. They thus become very covert because
22 they exhibit no UV, visible or IR stimulated output to
23 be observed by a counterfeiter.
24
25 The preferred elements for our dopants can be fused
26 with other elements in order to hide the presence of
27 the dopant element, or to alter its absorption
28 spectrum; or the oxide or salt of preferred element
29 itself can be directly mixed into, for example, a
30 printing ink or a batch composition for plastics
31 production etc. When the dopant is mixed with other

1 elemental compounds and where one of its admixture
2 compounds contains a substantial proportion by weight
3 of a particular range of atomic number (z) elements,
4 varying the proportion of this compound in the final
5 mix can vary the absorption spectrum of the final
6 inorganic mixture, thus essentially creating further
7 dopants.

8

9 The present invention depends on the incorporation of a
10 synthesised inorganic dopant into or onto the document
11 at any stage of its manufacture, including the printing
12 stage. These dopants are designed to have very complex
13 visible wavelength absorption spectra, measured in
14 either reflective or transmissive mode. The spectra
15 they exhibit are not found in printing inks or common
16 marbling substrates. This results in high signal-to-
17 noise ratio detection, and hence the ability to
18 identify the dopant in 10msec or less using low output
19 (c. 4W) bulbs as illuminants.

20

21 The dopant incorporation with its unique spectrographic
22 pattern gives independence from document soiling, wear
23 and tear etc, because it allows excellent signal-to-
24 noise ratio. Pattern recognition software to identify,
25 within 1 msec, the complex signature of our synthesised
26 dopants is readily available from suppliers in the
27 public domain, having been used in optical and nuclear
28 spectrometry for 30 years. Dopants in accordance with
29 the present invention can be incorporated singly,
30 mixed, or in separate areas to produce a "bar code", or
31 to simply confuse a forger. The dopants, depending on

1 composition, are either colourless or transparent, or
2 coloured, at the choice of the user. Dopants made in
3 accordance with the present invention provide high
4 optical absorption yet give optical transparency
5 because their absorption features are created at
6 wavelengths to which the human eye is insensitive.

7

8 For visible wavelength interpretation the preferred
9 method is to illuminate an area of at least 5mm² by a
10 ring of at least 6-8 200 μ optical fibres in a
11 concentric ring, and channel reflected light through an
12 inner 200 μ optical fibre to the wavelength detector. It
13 has been found that this number of optical fibres gives
14 sufficient signal for interpretation of the spectra,
15 however the present invention is not limited to this
16 method of detection of the spectrum or the number or
17 arrangement of optical fibres used in this detection
18 method. This eliminates the optical losses due to
19 lenses in much prior art, which in turn leads to the
20 processing speed of our system. CCD based wavelength
21 detectors, followed by A-D conversion for processing
22 are standard technologies in public domain electronics.
23 Our dopants are engineered to give no visible signal,
24 such as fluorescence, upon illumination by UV, visible,
25 or IR radiation and are hence not easily replicated as
26 has happened with fluorescent inks, and other emitting
27 technologies.

28

29 The advantages of the present invention will be readily
30 apparent when the spectra obtained from these dopants

1 is compared with those obtained from standard printing
2 inks, or colourisers in plastics etc. The standard
3 inks and the like give relatively unsophisticated
4 reflectance spectra - see for example Figures 1, 2, 3.
5 These show the visible reflectance spectrum of a
6 Pantone standard blue, green and red ink from a paper
7 print. Figures 4, 5, 6, 7 show the visible reflectance
8 spectra from the four dopants, Praesodymium Oxide, the
9 Neodymium Oxide, the Holmium Oxide and Thulium Oxide,
10 incorporated in a clear litho varnish and printed on
11 the same paper as that used to obtain the spectra shown
12 in Figs. 1, 2 and 3.

13

14 The prints obtained using dopants in accordance with
15 the present invention are completely colourless to the
16 eye. Figure 4 for example, shows many easily
17 identifiable peaks, troughs and turning points in its
18 spectrum with a shape easily distinguished from any ink
19 or colouring dopants. It is these unique features
20 which give the excellent signal-to-noise ratio, giving
21 the rapid identification ability of our system, with
22 excellent identification rates, and very low false
23 acceptances, together with high rejection for forged
24 copies.

25

26 The features, and/or slopes, of the reflectance spectra
27 can be shifted to create other dopants by incorporating
28 the dopants into inorganic compounds of the type
29 described later.

30

1 The use of visible wavelength spectrometry, as opposed
2 to IR or NIR wavelengths, makes possible many more
3 commercial applications. This is firstly because of
4 the reduced cost of components for the visible, and
5 secondly because the cheapest excitation source is a
6 common (4W) torch bulb which emits plenty of visible
7 light but very little IR. Hence IR and NIR techniques
8 require more powerful and costly excitation sources.
9 Also by moving to the visible we make it easy to
10 construct simple hand-held portable instrumentation
11 which again increases possible commercial applications.
12

13 Visible wavelength spectroscopy as revealed in the
14 prior art with application to security uses lenses or
15 mirrors and lamps to provide the illumination source.
16

17 Many suppliers, such as Oriel Corp. USA, now make
18 commercially available reflectance probes which are
19 about 6mm diameter overall and contain a ring of
20 illuminating fibres (200 μ diameter 6-8 in number)
21 surrounding a centre core of detecting fibres. Use of
22 these probes gives much improved signal-to-noise ratio
23 at the CCD array, or Si photodiode array, or other
24 detector. Using other off-the-shelf components the
25 output of the array spectrometer can be coupled to D-A
26 converters and operated from a laptop, hand-held
27 palmtop, or desktop PC computers. This can easily be
28 interfaced to standard computer software on production
29 lines for authentication at high speed - 10m/sec.

1 The dopants we have identified as working well can be
2 added to standard offset litho printing inks in a
3 manner known to those skilled in the art. It is added
4 in quantities up to about 30% by volume without
5 affecting the printing process, providing the dopants
6 have been micronised into fine powders of the order of
7 1-4 μ m diameter. If this step is omitted poor
8 uniformity printing results. Our dopants need add no
9 colour to the ink, so give a colourless invisible
10 printed strip onto the object to be protected.
11 Alternatively a colouring dopant can be selected to
12 blend in with an existing coloured scheme.

13
14 A major advantage of the dopants made in accordance
15 with the present invention is that they are cheap and
16 simple, not requiring the presence of complex expensive
17 chemicals.

18
19 The dopants can be applied to artefacts by any standard
20 deposition technique - air spray, lacquering, printing,
21 stamping.

22
23 The dopants could also be directly incorporated into
24 paper or plastic (for example) at time of manufacture
25 of said paper or plastic. For our techniques to work
26 it is not necessary that the dopants are added as a
27 superior layer or film, although in many cases this
28 will be the simplest and cheapest method. The fact
29 that our dopant/excitation/detector technology does not
30 require surface deposition can offer more
31 security/covertness to the process. It arises because

1 the excitation methods we are employing have ranges of
2 many tens of microns in common materials such as paper
3 and plastics. Since dopants in accordance with the
4 present invention need not be on the surface of the
5 document the forger is denied the opportunity to scrape
6 off samples from repeated small surface areas and
7 analyse them to look for "surprising" changes in
8 composition from area to area. Such changes give the
9 forger a clue that covert technology is being used in
10 that area.

11 The multiple peaks, troughs, and turning points
12 resulting give rapid, positive, unambiguous
13 identification of dopant presence (and hence object
14 authenticity) and allow multiple dopants to be used as
15 a further method of disguise, if required.

16

17 The preparation of the inorganic powders for doping to
18 permit identification by visible light is not limited
19 to the use of chemical compounds which could be formed
20 by precipitation from a solution because such compounds
21 are limited in numbers. It has been found that the
22 most useful compounds (those with the most distinctive
23 absorption spectra in the visible) could be formed by
24 fusion melting. Silicates, phosphates, borates have
25 been found to be the most useful starting points for
26 fusion, because they give transparent glass matrices.

27

28 In forming the required solids for powdering, the
29 chemical batch composition is not, for example, limited
30 to that required to produce, say, a glass. This is
31 because long range atomic order is not required in the

1 solid, since homogeneity is assured by micronising the
2 composition. Indeed in general terms we have found
3 that the best compositions are obtained where phase
4 separation of the melt temperature is imminent. This
5 point is determined experimentally for each
6 composition. Nor need the chemistry be limited to
7 stoichometric ratios such as to arrive at crystalline
8 compounds, e.g. as used to produce the commonplace
9 inorganic fluorescence powders added to printing inks.

10

11 In many compositions, the structure and magnitude of
12 the absorption peaks can be controlled over a wide
13 range by control of the gas atmosphere during the melt
14 phase. This is established by trial and error for each
15 composition by test melting each composition in air, in
16 a reducing atmosphere, and in an oxidising atmosphere
17 to determine the optimum methodology and conditions for
18 the absorption profile required.

19

20 In many compositions, the structure and magnitude of
21 absorption peaks can be controlled by including a
22 substantial quantity (>20% by weight) of a high atomic
23 number Z element in the batch composition (lanthanum,
24 bismuth, and strontium work well, as examples). Then
25 varying the content of this high Z element only gives
26 changes in position and magnitude of the absorption
27 peaks, from composition to composition. Different
28 absorption peak wavelengths and magnitudes from that
29 exhibited by the raw dopant before being incorporated
30 in a glass.

1 The effect of incorporating the dopant in a glass on
2 its spectrum can be seen in Figs. 8, 9, 10 and 11.

3

4 Fig. 8 shows a plot of the percent transmission against
5 wavelength (nm) for a raw Europium Oxide dopant powder.

6 Fig. 9 shows a plot of the percent transmission against
7 wavelength (nm) for a Europium Oxide dopant powder
8 incorporated in a glass and ground into a fine powder.

9 The substances contained in the glass are as given in
10 Table 1 below and the glass plus dopant is made in
11 accordance with the method given below Table 1 on page
12 14.

13

14 Simply from a visual inspection it can be seen that the
15 two spectra are very different.

16 The feature of the spectrum of Europium Oxide shown at
17 reference numeral 81 for the raw oxide powder that
18 occurs at a wavelength of 533 nm has been shifted to
19 531nm. A similar shift can be seen for the lower
20 wavelength peaks 83 and 93. In both cases, the shift
21 in wavelength was 2nm. The most significant difference
22 between the spectra of Fig. 8 and Fig. 9 is the presence
23 of the line in the spectrum of the Europium Oxide
24 contained in glass at 393nm. There is no similar line
25 in the raw powder spectrum.

26

27 Fig. 10 shows a plot of the percent transmission
28 against wavelength (nm) for a raw Erbium Oxide dopant
29 powder. Fig. 11 shows a plot of the percent
30 transmission against wavelength (nm) for an Erbium
31 Oxide dopant powder incorporated in a ground fine

1 powder glass. As with the sample used to obtain the
2 spectrum if Fig.9, the substances contained in the
3 glass are as given in Table 1 below and the glass plus
4 dopant is made in accordance with the method given
5 below Table 1 on page 14.

6

7 Fig. 10 shows, at reference numeral 101, the existence
8 of multiple peak structure occurring from a minimum
9 point at 654nm to approximately 700nm. It can be seen
10 that these features are absent from the spectrum of
11 Fig. 11 as indicated at reference numeral 111.

12

13 Fig.10 also has multiple peak structure occurring from
14 a minimum value at 521nm up to approximately 600nm.
15 These features are absent from the spectrum of Fig. 11
16 as can be seen at reference numeral 113.

17

18 We have shown our dopant technology to work in a wide
19 variety of compounds, including, but not limited to,
20 silicates, borosilicates, borates and germanates.

21

22 The following are a number of examples of the
23 composition and method of manufacture of a doped glass
24 in accordance with the present invention.

25

26 Example 1

27

28 A glass batch of a typical suitable composition is as
29 follows.

30

1

2

Compound	Wt %
SiO ₂	35%
B ₂ O ₃	40.0
Na ₂ O	8.5
K ₂ O	8.5
Al ₂ O ₃	1.0
MgO	4.0

3

4

Table 1

5

6 To this batch was added 0.1 to 25 wt% of Eu₂O₃. All
7 powder sizes can be used but approximately 250 mesh is
8 preferable. A wide range of crucibles can be used, a
9 Platinum crucible was used in this case. The final
10 batch is mixed and homogenised then it is added to the
11 crucible heated to 845°C. The temperature is then
12 increased at a rate of approximately 5 °C/min to 1200 °C
13 the final melt temperature. It has been found that
14 good quality melts are produced by holding the melt at
15 the final temperature for between 2 and 2.5 hours
16 before powdering the glass. For absorber products not
17 visible to the naked eye, the natural emissions of Eu₂O₃
18 may be quenched by the use of high concentrations of
19 Eu₂O₃ or by the inclusion of small < 1% quantities of
20 nickel oxide, silver oxide or lead oxide as
21 luminescence quenchers.

22

1 The following compositions may also be used

Compound	Wt (g)	Compound	Wt (g)	Compound	Wt (g)
SiO ₂	55	SiO ₂	70	SiO ₂	50
B ₂ O ₃	65	B ₂ O ₃	80	Be ₂ CO ₃	20
Na ₂ CO ₃	29	Na ₂ CO ₃	29	SrCO ₃	20
K ₂ CO ₃	20	K ₂ CO ₃	20	Na ₂ CO ₃	10
Li ₂ CO ₃	5	Li ₂ CO ₃	5	K ₂ CO ₃	10
Al ₂ O ₃	2	Al ₂ O ₃	2	Li ₂ CO ₃	5
MgO	8	MgO	5	Al ₂ O ₃	2
				MgO	5

2

3

Table 2

4

5

Compound	Wt (g)	Compound	Wt (g)
SiO ₂	35	SiO ₂	55
B ₂ O ₃	80	B ₂ O ₃	65
Be ₂ CO ₃	40	Na ₂ CO ₃	29
Na ₂ CO ₃	29	K ₂ CO ₃	20
K ₂ CO ₃	20	Li ₂ CO ₃	5
Li ₂ CO ₃	5	Al ₂ O ₃	2
Al ₂ O ₃	2	MgO	8
MgO	8		

6

7

Table 3

8

9

10

11

12

1 Another suitable composition is of the type

2

3

Compound	Wt %
SiO ₂	51
B ₂ O ₃	13
Al ₂ O ₃	8
MgO	6
CaO	10
SrO	4
ZnO	4

4

5 Table 4

6

7 This is particularly suitable as a base for
8 incorporating dopants for visible wavelength absorption
9 detection because all the base elements have largely
10 unfeatured absorption spectra.

11

12 Dopants have also been successfully incorporated into
13 glass matrices with the following ranges of chemical
14 composition.

15

16 30-56wt% SiO₂,
17 5-35wt%, La₂O₃/Bi₂O₃/Sr₂O₃,
18 2-33wt% Li₂O/K₂O/Na₂O,
19 0-6% Al₂O₃
20 wherein the La, Bi, Sr are examples of a suitable high
21 Atomic number component.

22

1 Incorporation of all three alkaline earth compounds,
2 plus BaO, gives much reduced melting temperatures.

3

4 Preferred elements for dopant fabrication for visible
5 wavelength absorption system

6

7	Barium	Zinc
8	Lanthanum	Samarium
9	Lead	Praesodymium
10	Magnesium	Europium
11	Strontium	Boron-10
12	Titanium	Neodymium
13	Chromium	Holmium
14	Iron	Thulium
15	Caesium	Cadmium
16	Molybdemum	Antimony
17	Nickel	Erbium
18	Tungsten	Lutecium
19	Cobalt	Tin
20	Sodium	
21	Potassium	
22	Terbium	

23 Table 5

24

25 Improvements and modifications may be incorporated
26 without deviating from the scope of the invention.

1 **CLAIMS**

2

3 1. A method of providing a document with a covert
4 security feature in which the document is provided with
5 at least one dopant, the dopant being of a material
6 which can be identified by examination of its response
7 to visible wavelength photon radiation.

8

9 2. A method of providing a document with a covert
10 security feature as claimed in Claim 1, in which the
11 dopant comprises one or more inorganic compounds.

12

13 3. A method of providing a document with a covert
14 security feature as claimed in Claim 1 or Claim 2, in
15 which the dopant comprises one of, or a combination of
16 the elements listed in Table 5, in elemental form or as
17 an oxide or salt.

18

19 4. A method of providing a document with a covert
20 security feature as claimed in any preceding Claim, in
21 which the dopant is mixed with a quantity of an element
22 or its salt or its oxide with an atomic number greater
23 than 36.

24

25 5. A method of providing a document with a covert
26 security feature as claimed in Claim 4 in which the
27 element or its salt or its oxide is Strontium,
28 Lanthanum or Bismuth.

29

30

1 6. A method of providing a document with a covert
2 security feature as claimed in any preceding Claim, in
3 which the dopant is mixed with ink and the resulting
4 mixture is applied to the document.

5

6 7. A method of providing a document with a covert
7 security feature as claimed in any preceding Claim in
8 which the dopant is fused in a glass before being
9 applied to the document.

10

11 8. A method of providing a document with a covert
12 security feature as claimed in Claim 7 in which the
13 glass is made of silicates and/or phosphates and/or
14 borates.

15

16 9. A method of providing a document with a covert
17 security feature as claimed in Claim 7 or Claim 8 in
18 which the or each dopant is micronised into a fine
19 powder.

20

21 10. A method of providing a document with a covert
22 security feature as claimed in one of Claim 7 to Claim
23 9 in which each particle of the micronised fine powder
24 has a diameter of 1-4 μ m.

25

26 11. A method of providing a document with a covert
27 security feature as claimed in any preceding Claim in
28 which the dopant is such that, when the document is
29 illuminated with broad-band visible light to produce a
30 reflectance spectrum with frequency components

1 generated by the dopant and by other reflecting
2 substances contained in the document, said spectrum
3 containing minimal frequency overlap between the
4 components of the spectrum generated by the dopant and
5 that part of the spectrum generated by other substances
6 contained in the document.

7

8 12. A method of providing a document with a covert
9 security feature as claimed in any preceding Claim in
10 which the dopant is such that, when the document is
11 illuminated with broad-band visible the frequency
12 components generated by the dopant are invisible to the
13 human eye.

14

15 13. A method of providing a document with a covert
16 security feature as claimed any preceding Claim in
17 which the spectrum of the dopant can be shifted to a
18 higher or lower wavelength.

19

20 14. A method of providing a document with a covert
21 security feature as claimed in any preceding Claim in
22 which the spectrum of the dopant can be shifted to a
23 higher or lower wavelength by alteration of the
24 composition of the glass in which it is fused.

25

26 15. A method of providing a document with a covert
27 security feature as claimed in any preceding Claim, in
28 which the spectrum of the dopant is alterable by
29 alteration of the reaction temperature and/or pressure
30 at which the glass is made.

1

2 16. A document provided with a covert security feature

3 by the method any of the preceding Claims.

4

5 17. A dopant for use in providing a document with a

6 covert security feature, comprising one or more

7 combination of the elements listed in Table 5, in

8 elemental form or as an oxide or salt, in finely

9 divided form.

10

11 18. A method of making a dopant, in which one or a

12 combination of the elements listed in table 5, in

13 elemental form or as an oxide or salt, is fused in a

14 glass and subsequently micronised.

15

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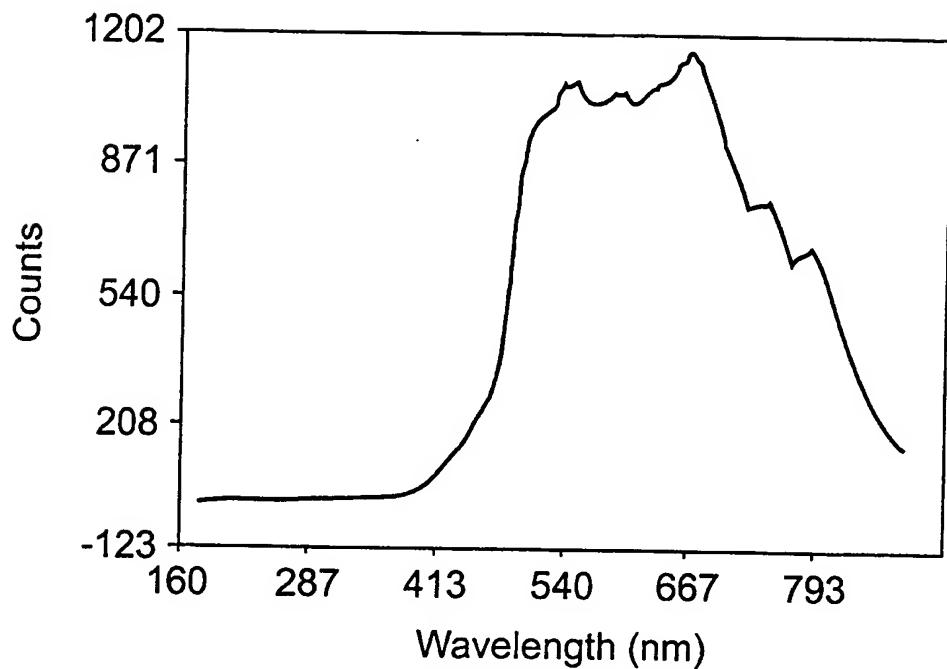


Fig. 1

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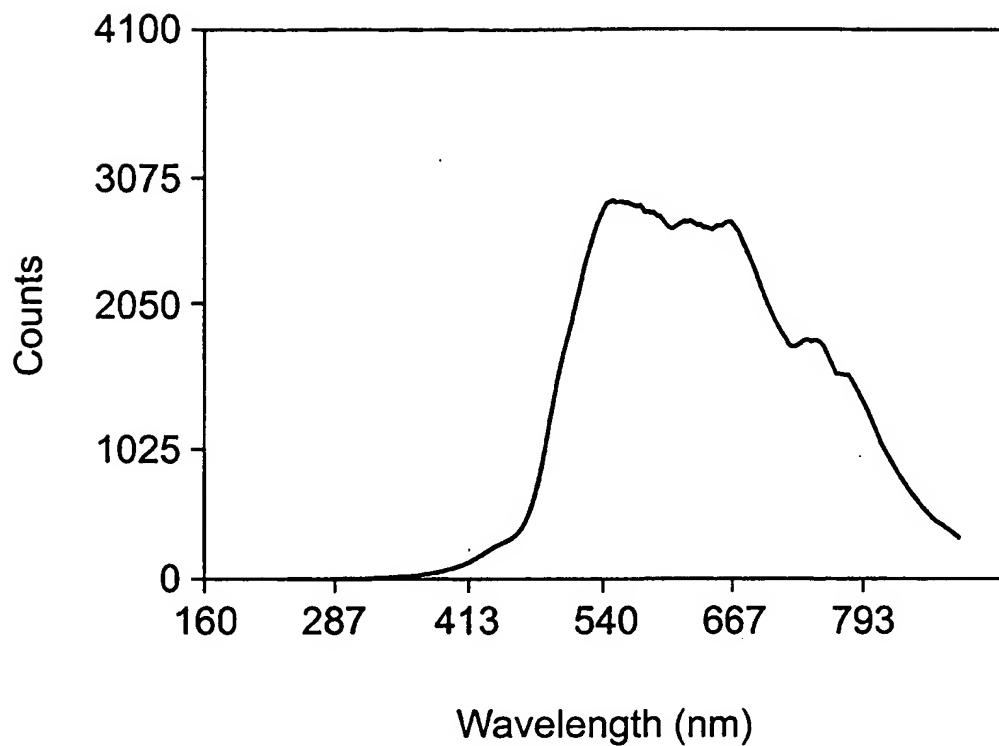


Fig. 2

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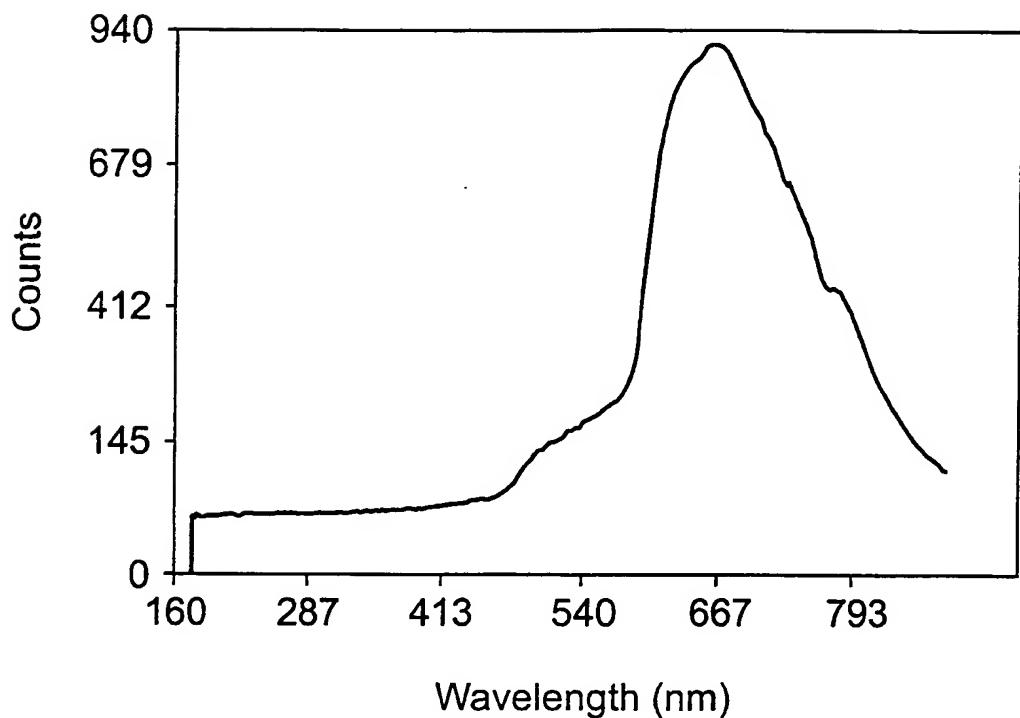


Fig. 3

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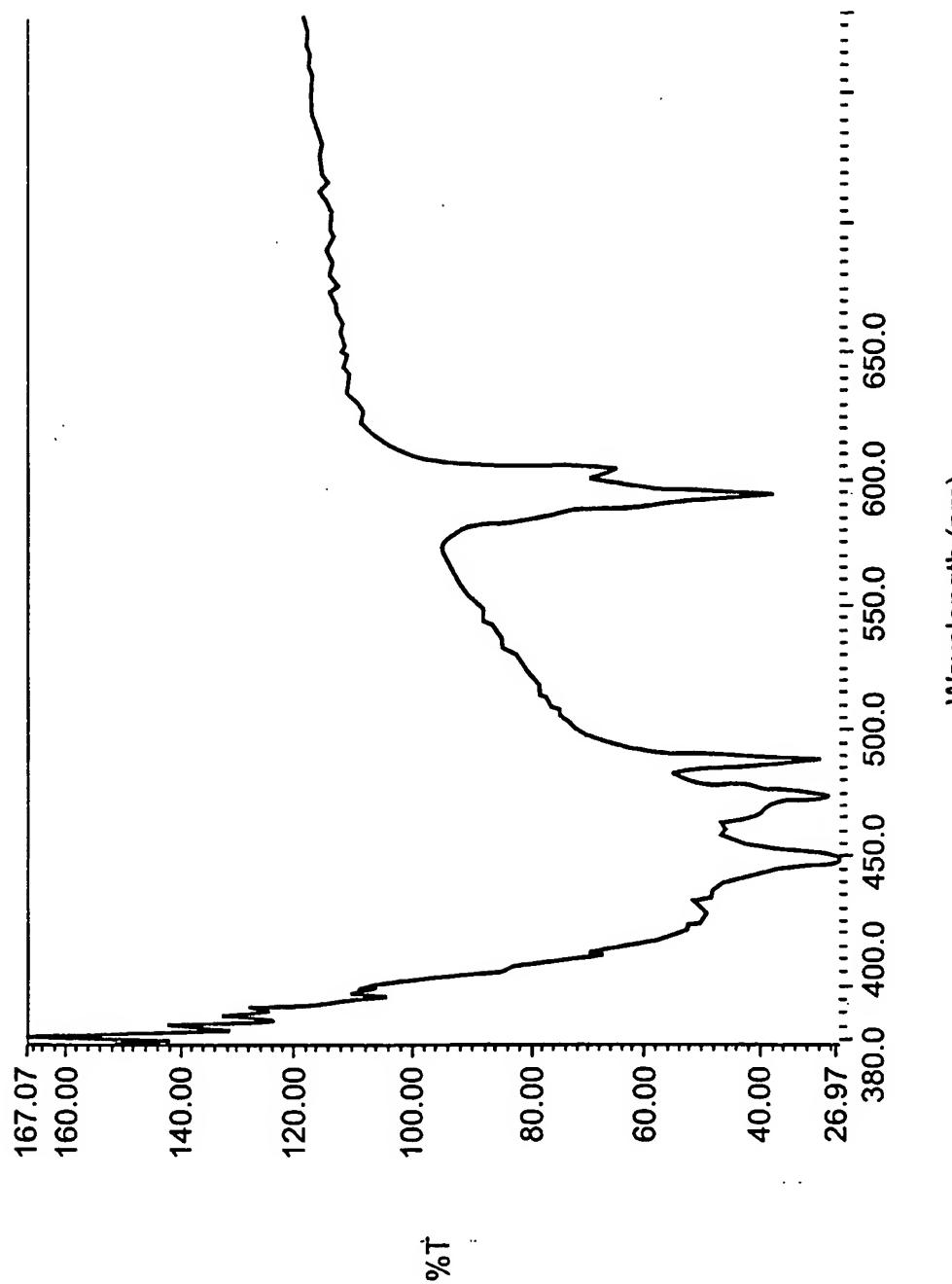


Fig. 4

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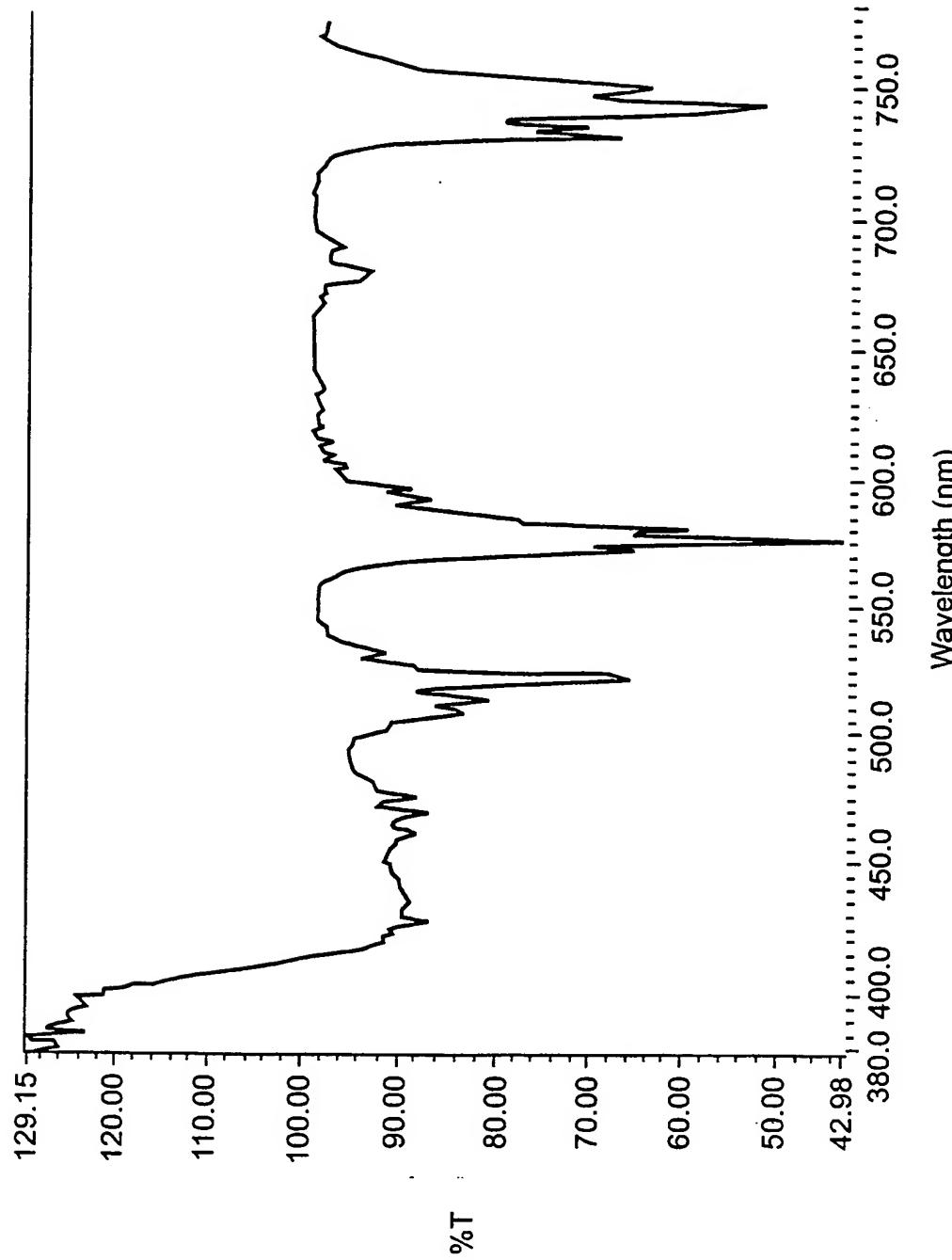


Fig. 5

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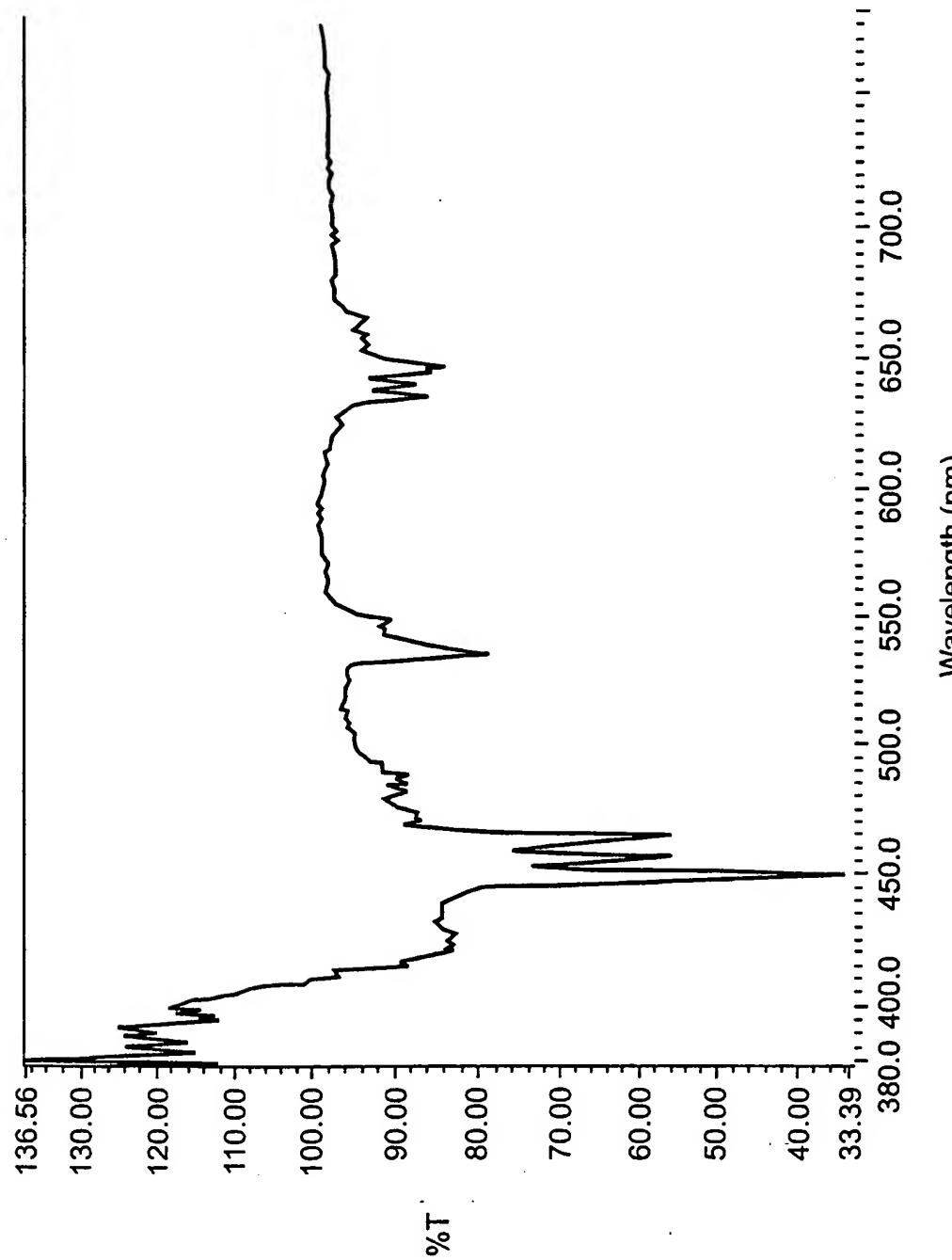


Fig. 6

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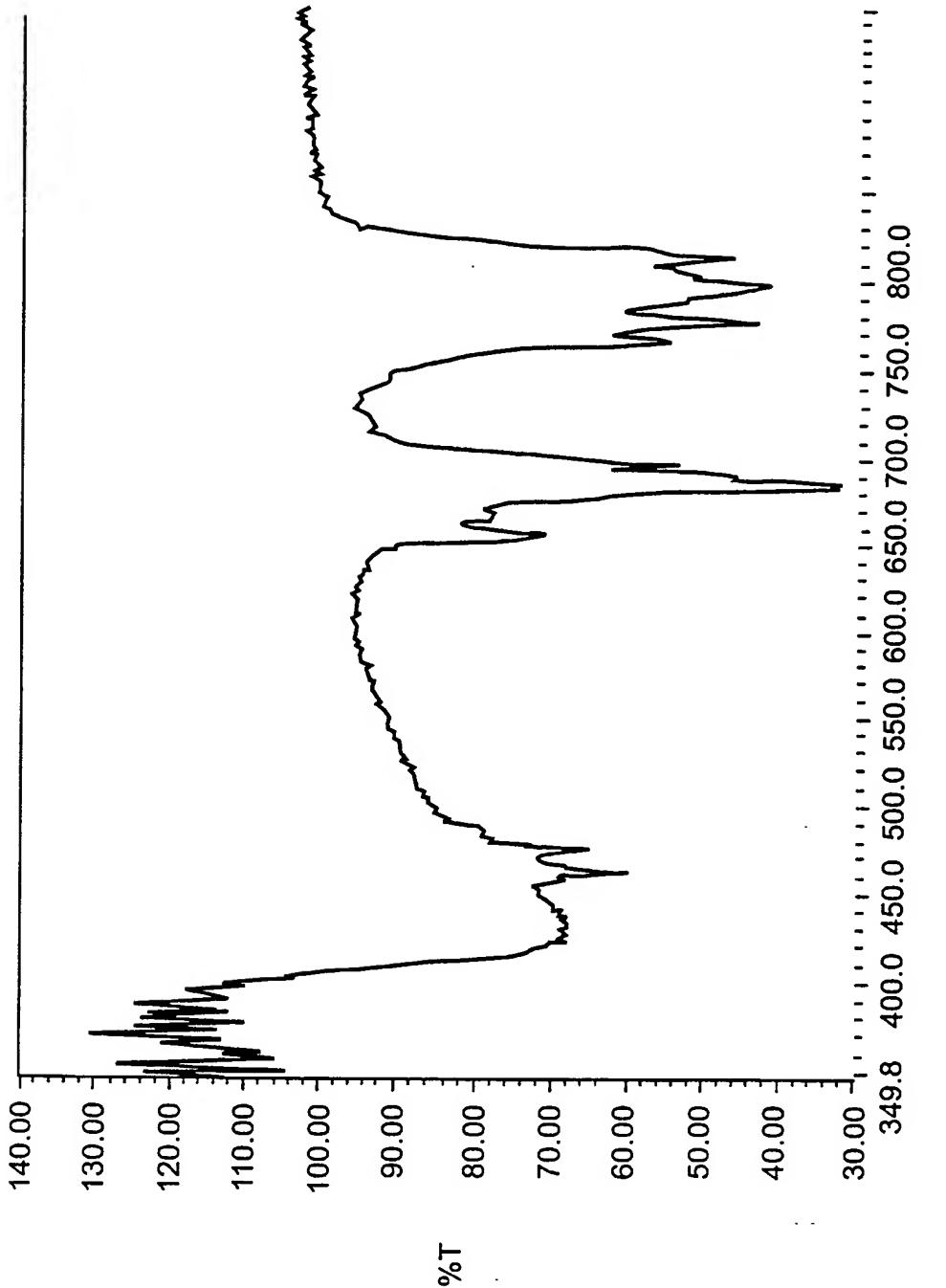


Fig. 7

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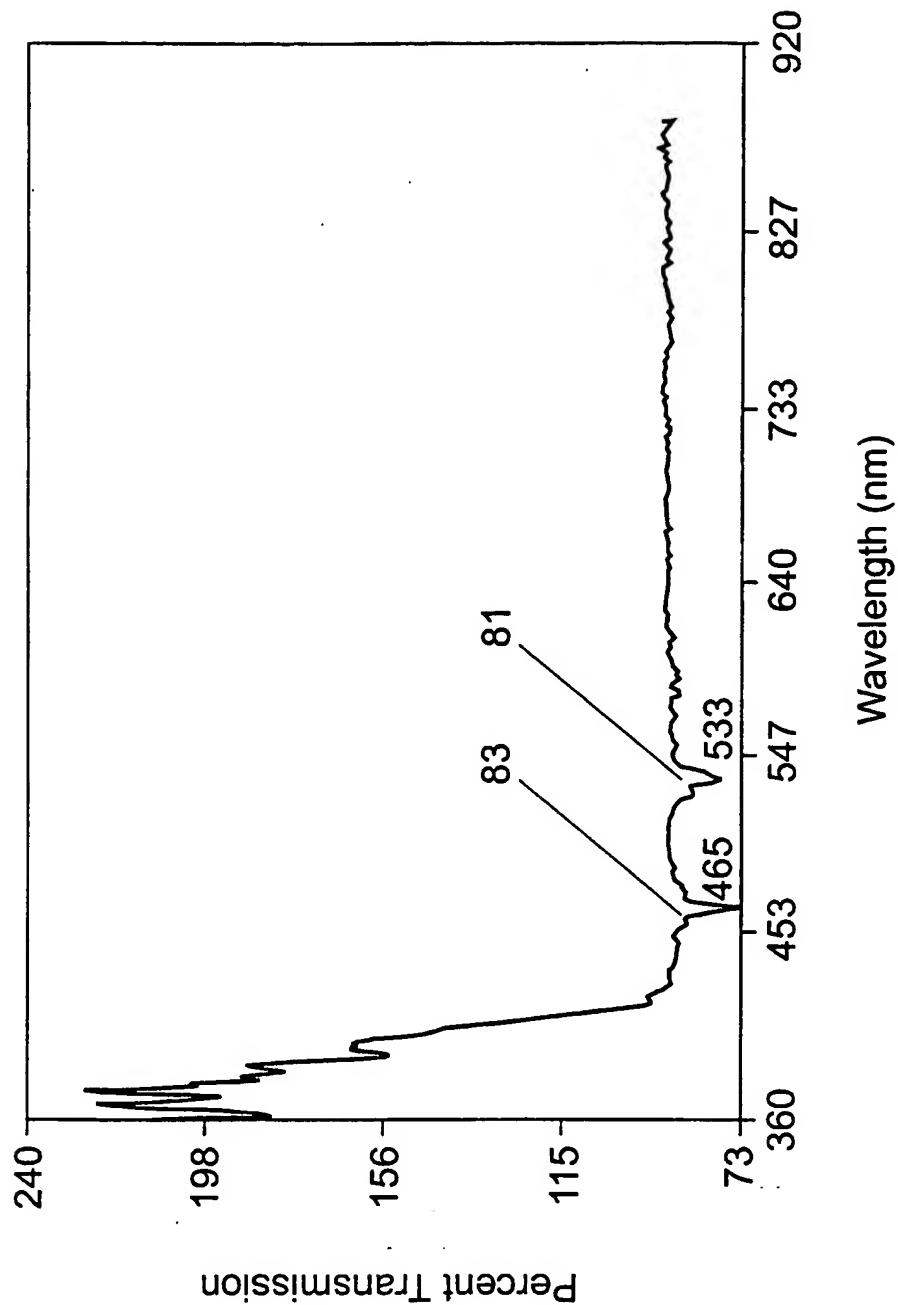
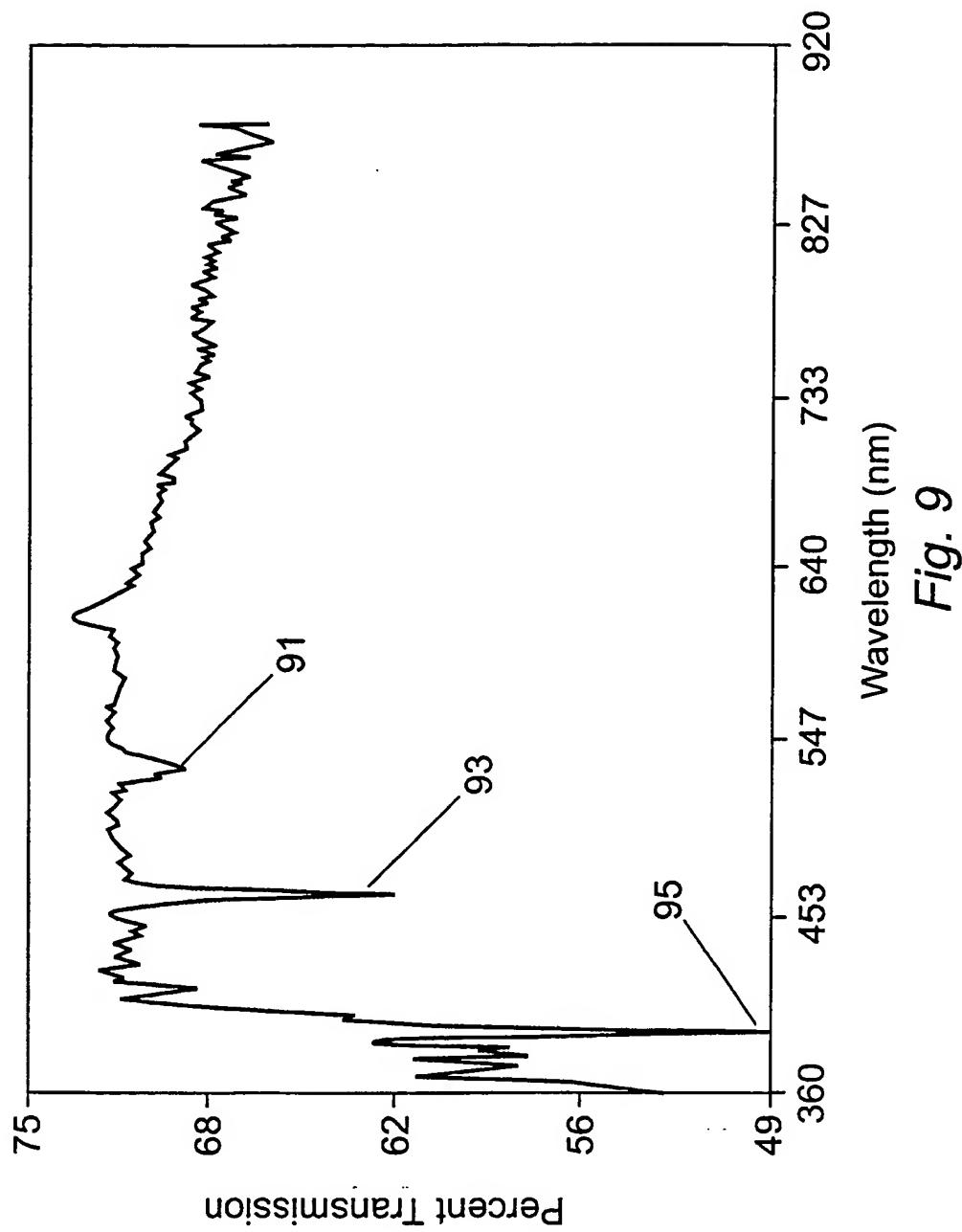


Fig. 8

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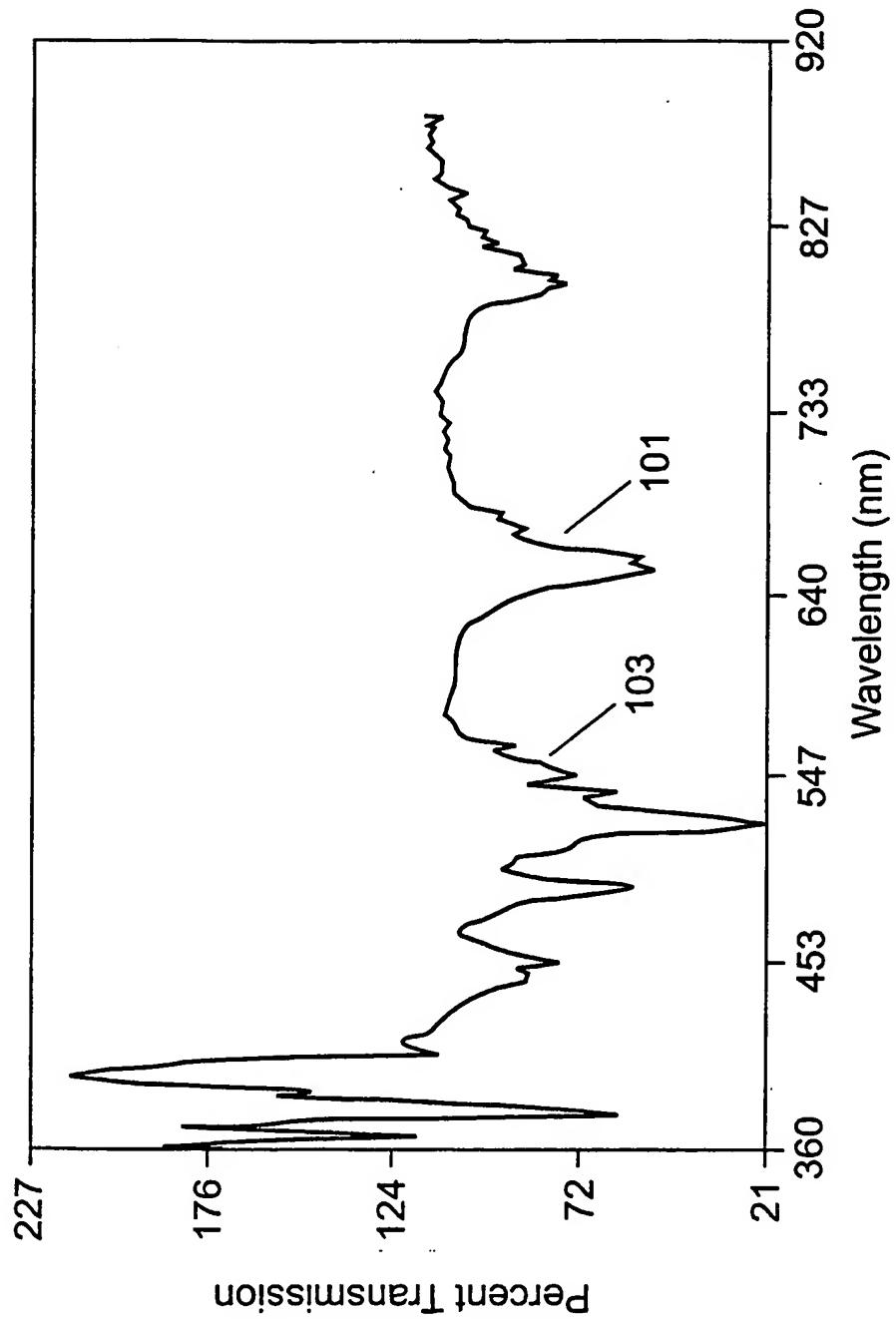


Fig. 10

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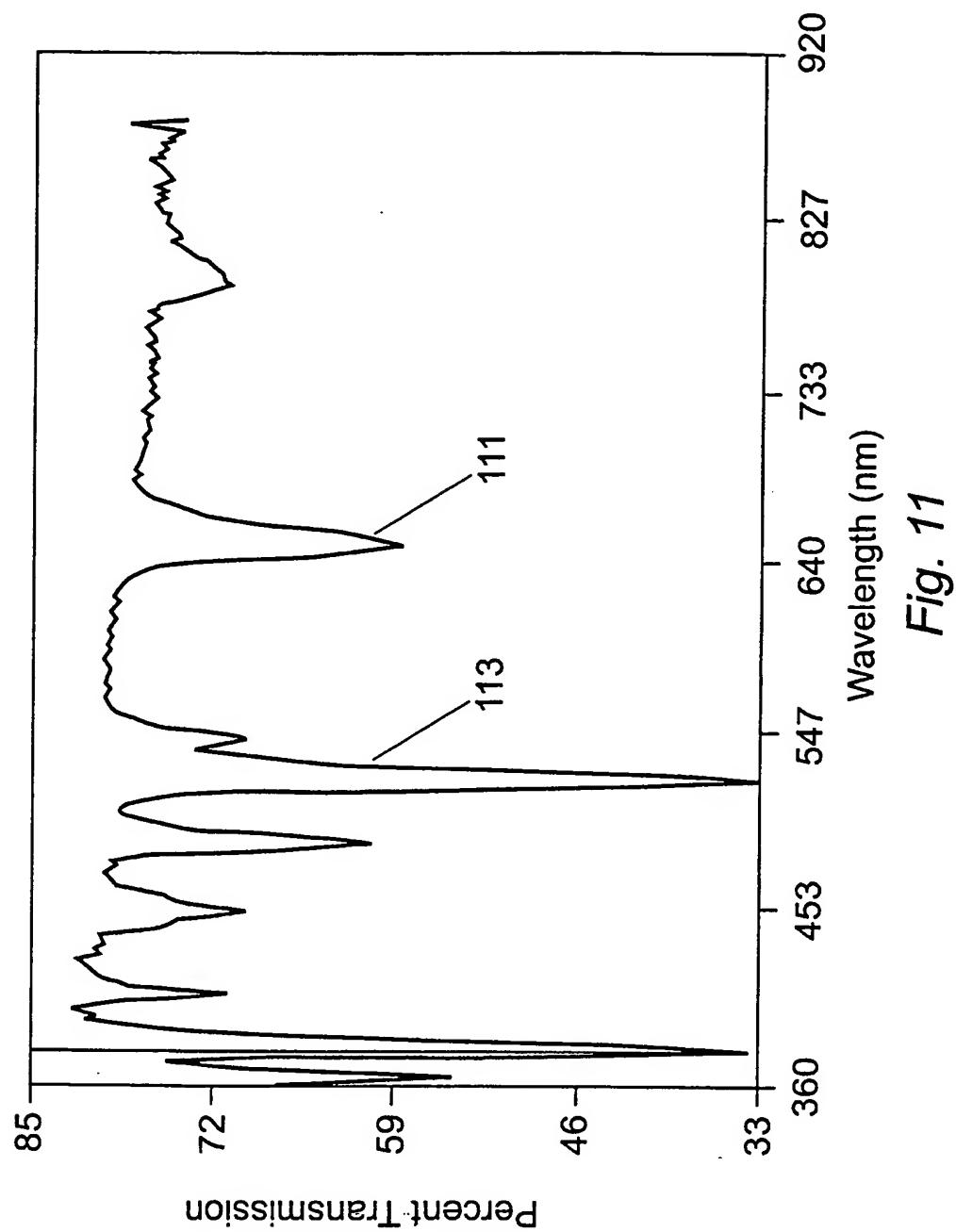


Fig. 11

INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/03692

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B41M3/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B41M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the International search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 81 03509 A (GAO) 10 December 1981 (1981-12-10) page 7, line 9 -page 8, line 5 page 11, line 17 - line 31 page 13, line 17 - line 29 page 14, line 21 -page 15, line 3 page 19, line 11 - line 13; claims 9,10 ---	1-5,7, 9-14, 16-18
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Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

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Date of mailing of the International search report

08/02/2000

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INTERNATIONAL SEARCH REPORT

Int. Search Application No

PCT/GB 99/03692

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Y	column 1, line 14 - line 22; claim 1; figure 2	8,15

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